Compliance Cell Size
August 2015

We need to determine the size of the compliance cell for our Puget Sound dissolved oxygen efforts. The compliance cell is the volume of water that is compared to the water quality standards; it may be different than the model cell size used in the water quality modeling. This paper provides background information to help determine what size compliance cell we want to use.

Page 1: Summary of compliance cells for various TMDLs and other projects.
Page 2: A visual representation of those compliance cells from page 1.
Page 3: Options for compliance cell size
Pages 4+: Appendix maps showing Puget Sound model cell size and background information on other TMDLs.

Compliance Cell Sizes

Project	Cell Size (length x width x thickness)	Surface Area (km²)	Volume at Bottom (m³)	Model Cells Combined?	Notes
Budd Inlet model	400m x 140m x 1-3m	0.06	120,000	No	[1]
South Puget Sound model	500m x 500m x Variable (4m-30m)	0.25	1,000,000	Not yet	[2]
Salish Sea model	880m triangles (variable from 350-3000m) x 3m [3]	0.39	1,200,000	Not yet	[4]
303(d) listing grids	760m x 1,100m x worst depth (0.5 m increments for EAP MM)	<=0.84	<=420,000	No	[5]
Mixing Zones in Puget Sound	61m radius x water column depth (1-4m in East Bay and Eld Inlet)	0.01	29,000	No	WAC 173-201A-400
Spokane TMDL	1070m x 437m x 36m	0.47	17,000,000	Yes	See appendix
Sinclair / Dyes TMDL	100m x 50m x 1m	0.005	5,000	Yes	See appendix
Lake Whatcom TMDL	800m x ~650m x 22m	0.52	11,000,000	Yes	See appendix
Pend Oreille TMDL	800-11,000m x 200-1000m x 5-30m	3.5	62,000,000	Yes	See appendix

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[1] Based on visual comparison to map scale
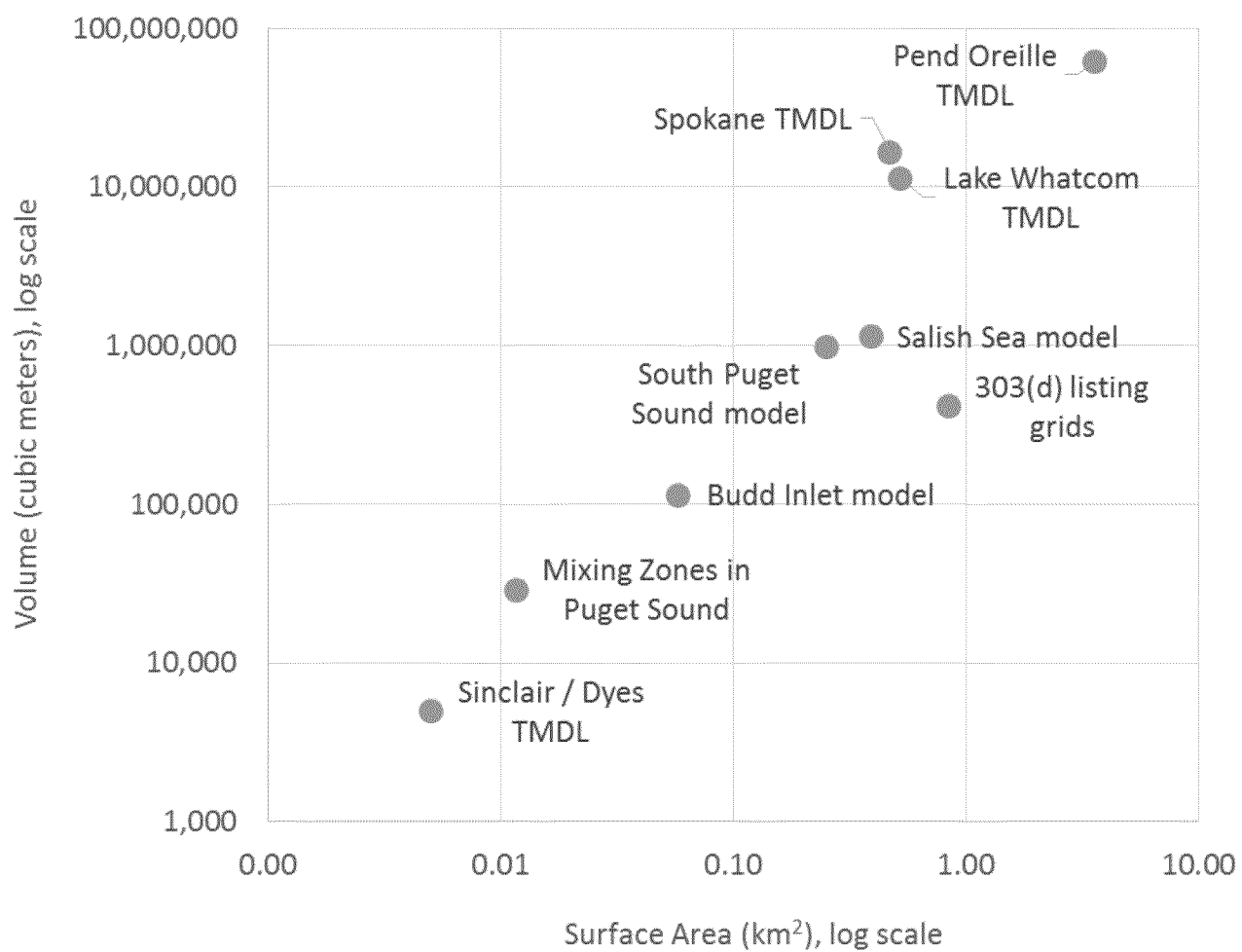[2] https://fortress.wa.gov/ecy/publications/documents/1403015.pdf
[3] In a sigma stretch system, there are always the same number of layers regardless of depth so will vary with where in Budd or Eld Inlet. It also varies with the tidal elevation, which is a large portion of the depth of Budd and Eld Inlets near the back. Back of the envelope: Depth of Budd and Eld (generic locations near the south end) is about 20 feet and bottom layer is 15% of the column so 3 m.
[4] http://www.ecy.wa.gov/programs/wq/PugetSound/pshydmodelrpt11302009.pdf
[5] The grids are 45 second x 45 second; they get smaller further north. Many cells are partial cells of much smaller size.

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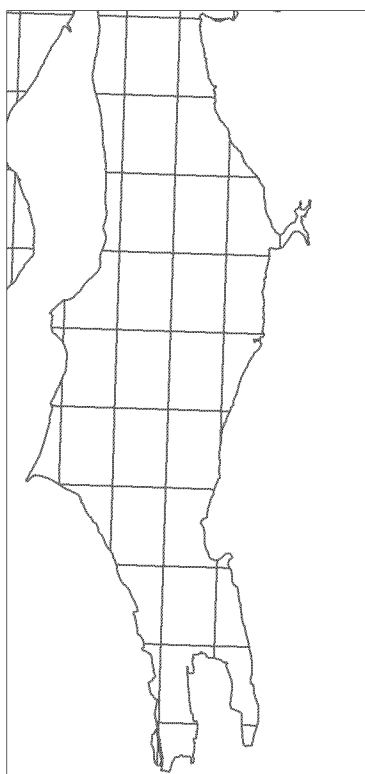Compliance Cell Size for TMDLs and Other Projects

Options for Compliance Cell Size

Andrew Recommends #1, #3, or #4

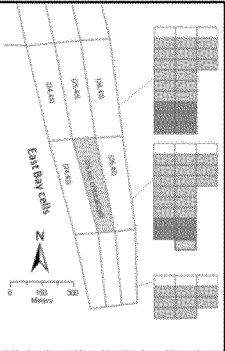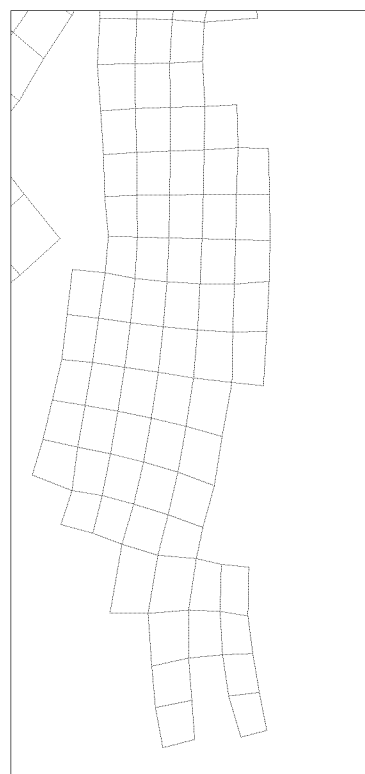| Option	Effect on:	
	Surface Area (km²)	Volume at Bottom (m³)
1. Use the current model cell, worst layer. a. Smallest compliance cell option (still falls within the large range of currently-used compliance cell sizes) b. Matches previous interpretations for Budd Inlet and South Puget Sound c. Simple	None	None
2. Use the current model cell; average all layers below the pycnocline. (The pycnocline is a boundary separating two liquid layers of different densities. A large density difference, due to salinity and temperature, between surface waters and deep ocean water prevents vertical currents. Because the pycnocline zone is stable, it acts as a barrier for surface processes.) a. Would need to determine the pycnocline in Puget Sound b. Falls within the large range of currently-used compliance cell sizes	None	None to ~3x increase in East Bay
3. Combine model cells in groups to match the size 303(d) listing grid; average all layers below the pycnocline. (Model cells whose centroid are in one 303(d) listing grid are combined) a. Would need to group cells (depending on how they are grouped, there will still be small compliance cells just like we have some very small 303(d) cells) b. Falls within the large range of currently-used compliance cell sizes	None to ~9x increase	None to ~20x increase in East Bay
4. Combine portions of inlets that are homogeneous in terms of physics, chemistry, and biology. Given how a TMDL works, this only needs to be done for the worst case area(s), not everywhere. a. Difficult and contentious to determine b. Only need to merge cells on a site-by-site basis	TBD	TBD

Appendices
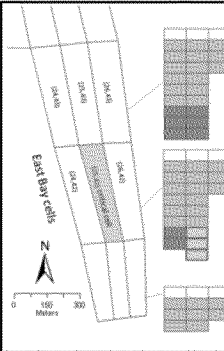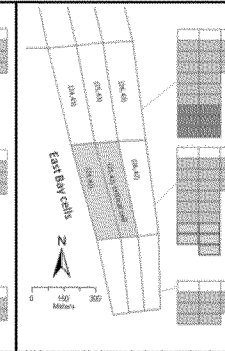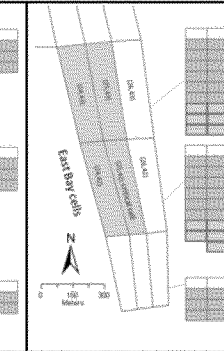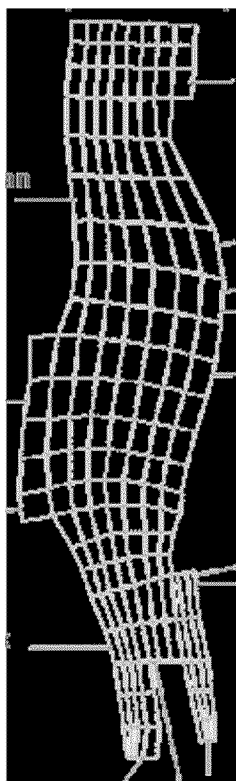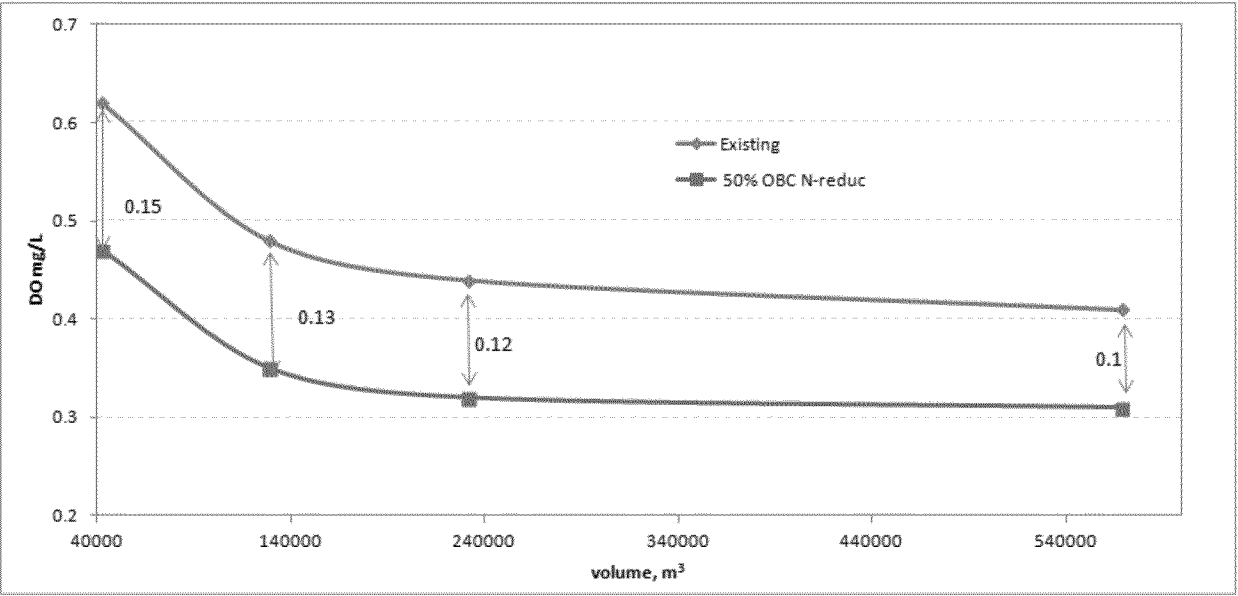

Budd Inlet Model (pink)   303(d) listing grids (green)   South Puget Sound model (blue)

DO standard violation under different combinations of cells and layer (Budd Inlet model)

	Horizontal and Vertical spatial extent				
Daily Min. Existing	Max violation, mg/L	0.62	0.48	0.44	0.41
	Number violations	133	62	52	38
	Percent violations (%)	57	26.7	22.4	16.4
	Max cont. Duration, days	67	42	24	20

Daily Min. (4c) 50% red_OBC	Max violation, mg/L	0.47 (24.2 % reduction)	0.35 (27%)	0.32 (27% reduction)	0.31 (24.4 % reduction)
	Number violations	123 (7.5 % reduction)	54 (13% reduction)	39 (25% reduction)	32 (16% reduction)
	Percent violations (%)	53	23.3	16.8	13.8
	Max cont. Duration, days	27 (60% reduction)	24 (43% reduction)	20 (16% reduction)	20 (0% change)

TMDL Name	Spokane DO
Physical size of the compliance area (the unit of water that was compared to the water quality standards for purpose of compliance) - length, width, and thickness in meters:	L=1070.8m; avg W=437m; D=44m *layers below 8m in the critical segment were averaged (volume weighted average)
Is the "compliance area" the same size of the model grid cells, or did we average model cells over space?	Length is equal to a model segment. The depth is the average of 1m layers below 8 m.
If we averaged model cells over space, how did we average and why did we average?	Every 4 hours the model would calculate the volume average DO concentration of model layers in the model segments below a depth of 8 m. This was done for each Lake Spokane model segment, and the lowest value over the course of the day would be used as the daily minimum, volume-averaged DO. At the end of each half-month period, the average of these daily mins was calculated and used as the half-month value. The critical segment was identified as the segment with the largest DO deficit when compared to a "no source" scenario. Averaged for the following reasons: 1. At the time of the decision we had only used 1D models such that a model "segment" represented the water column average. We did not have any guidance for how to interpret model results using a 2D model. 2. In doing scenarios to meet the 0.2 mg/L allowable DO deficit I noticed that a significant amount of loading had to be changed (reduced or increased) to meet very small changes in DO near the allowable limit (e.g., to go from a deficit of 0.21 to 0.20 or to increase from 0.19 to 0.20mg/L) that appeared to be influenced by numeric dispersion between 1m layers in a segment, i.e., numeric noise. Averaging the layers reduced the numeric noise in the results and increased the precision of the predictions. 3. Averaging increased my (and the dischargers) confidence in predicting DO deficits.
Other relevant information / notes	

TMDL Name	Lake Whatcom
Physical size of the compliance area (the unit of water that was compared to the water quality standards for purpose of compliance)	800m x ~650m x 22m
Is the "compliance area" the same size of the model grid cells, or did we average model cells over space?	Two segments were combined
If we averaged model cells over space, how did we average and why did we average? **Other relevant information / notes**	The goal was to minimize selection while not masking non-compliance. The end result was selecting the entire water column of the two segments of Lake Whatcom that contained the deepest water and including the May-October period of time. *How we got there.* Spatial selection. Using the entire lake masked small changes due to dilution effect. The original 303(d) listing was based on decline in the hypolimnion of the site with deepest water in Basin 1. Defining which model cells are part of hypolimnion requires some judgment and selection is subject to errors of including too much or too little but a selection of Clearly Hypolimnion was used as test of "This demonstrates impairment". Then we tested does including entire water column mask or dilute impairment. It did not. Next the adjacent segment that was the same depth was included those two had same scale of impairment. But as shallower segments were included the scale of the impairment started to drop off. That is we had more water but not necessarily more water that was impaired. Whereas adding two segments with the same depth we double water and double quantity that was impaired. Temporal Selection. The stratification of Basin 1 usually starts in May and ends by the end of October. Changes in DO when the lake is not stratified would be driven by circulation and hydrodynamics ability to move oxygen from the surface to deeper parts of the lake. So we focused on the entire part of the year when the hypolimnion is isolated and allowed a couple of weeks on either end to be included. Because the impairment was based on a rate of decline it did not provide a well-defined window of time. One of our early discoveries was that as the lake got worse the rate of decline slowed. The rate of decline stayed the same. That is because the HDOR is calculated using affixed window of time. And if you are going to zero before the end of the time window you still get the same rate of decline as if you reach zero on the last day of the window. That is how we selected the Cumulative Volume approach. By selecting the entire growing season and measuring total volume in each 0.1 mg/L bin no information is lost by larger windows of time so we made sure we had a window big enough to capture the entire duration of the hypolimnion. Did we average model cells – No we aggregated model cells. There was a bit of averaging when I published cumulative volume figures in that I divided by number of Days. Why - People have talked about adding oxygen so I wanted them to understand how much oxygen was missing and putting it in to an average daily deficit helped with communication. We couldn't talk about a maximum day because that didn't really work out. I could have left it as total in the half of a year and the only change would have been labels as the shape would be the same. Other considerations. If there are scenarios with different volumes you have to decide are you looking at minimizing how much oxygen at very low levels (the approach I took) or how much area has lots of oxygen (could lead to eutrophication is good because of daytime production from primary productivity). Or as an alternative looking at the percentage of the total volume in each bin.

TMDL Name	Sinclair / Dyes
Physical size of the compliance area (the unit of water that was compared to the water quality standards for purpose of compliance) - length, width, and thickness in meters:	Model cells equivalent to a 200-m radius around (a) mouths of rivers/streams and (b) WWTP outfalls
Is the "compliance area" the same size of the model grid cells, or did we average model cells over space?	Averaged over two model cells, each one approximately 50m x 50m x 1m
If we averaged model cells over space, how did we average and why did we average?	Page 32 – "Ecology determined the grid cells are smaller than the surface area corresponding to a default mixing zone for a point source discharge. ... The area occupied by two grid cells corresponds approximately to the area for a default mixing zone. Based on this assessment, Ecology determined that for regulatory purposes, i.e., for comparison with the marine water quality standard, for any nine-cell canary node, the average FC concentration for the two grid cells with the highest concentrations in the canary node would represent the compliance area for determining exceedances of the marine water quality standard (see Appendix G)."
Other relevant information / notes	The WQIR/IP includes extensive description of the process and results. This resulted from extensive discussions with stakeholders and a consensus approach. Report includes results for individual grid cells plus averaging over the highest 2, 3, 4, 6, or 9 grid cells. https://fortress.wa.gov/ecy/publications/documents/1110051.pdf

TMDL Name	Pend Oreille
Physical size of the compliance area (the unit of water that was compared to the water quality standards for purpose of compliance) - length, width, and thickness in meters:	Length: Reaches varied from 800m-11,000m Width: Width of river (200m typical; up to 1000m at Metaline) Thickness: Depth of river (up to 30m?)
Is the "compliance area" the same size of the model grid cells, or did we average model cells over space?	Layers were pooled
If we averaged model cells over space, how did we average and why did we average?	Pooled layers and multiple segments into reaches
Other relevant information / notes	https://fortress.wa.gov/ecy/publications/documents/1010065.pdf